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A Foundation for Interoperability in Next-Generation Product Development Systems

U.S. industry spends billions of dollars as a result of poor interoperability between computer-aided engineering software tools. While ongoing standards development efforts are attempting to address this problem in today's tools, the more significant demand in next-generation tools will be for representations that allow information used or generated during various product development activities to feed forward and backward into others by way of direct electronic interchange. Although the next generation of tools has the potential for greatly increased benefits, there is also a potential for the cost of poor interoperability to multiply. Research currently underway is working to develop representations of information that are unavailable in traditional CAD/CAM/CAE tools, to support the exchange of product information in a distributed product development environment. This presentation will describe a vision of next-generation product development systems and a core representation for product development information on which future product development systems can be built.

Presented by Simon Szykman

Dr. Simon Szykman is a mechanical engineer in the Manufacturing Systems Integration Division at NIST and previously served as a National Research Council Postdoctoral Research Associate. He has a B.S. in Mechanical Engineering from the University of Rochester, and a M.S. and Ph.D. in Mechanical Engineering from Carnegie Mellon University. He recently served as the Program Manager for the Advanced Technology Program (ATP) Technologies for the Integration of Manufacturing Applications (TIMA) program. He is currently leading a multi-project effort in Intelligent and Distributed Product Development that involves the development of knowledge representations and computational tools for modeling of design artifact information, to support interoperability in next-generation CAE systems.

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Information Technology
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A Foundation for Interoperability in Next-generation Product Development Systems

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Outline

- Background and Motivation
- Vision for Next-generation Product Development
- Intelligent and Distributed Engineering Design: Areas of Research
  - Foundations for knowledge-based interoperability
  - Architecture for design repositories
- Demonstration

Motivation

- Traditional product development
  - Co-located design teams
  - Design databases contain geometry and documentation
  - Much design knowledge is not stored/exchanged electronically
- New product development paradigm:
  - Distributed teams
  - High level of outsourcing
  - Heterogeneous computer-based tools
  - Network-based exchange and collaboration
  - Increased reliance on knowledge
- Design process and methodology may be organization-specific. No one process is best. Infrastructure and models should be independent of design process

Motivation

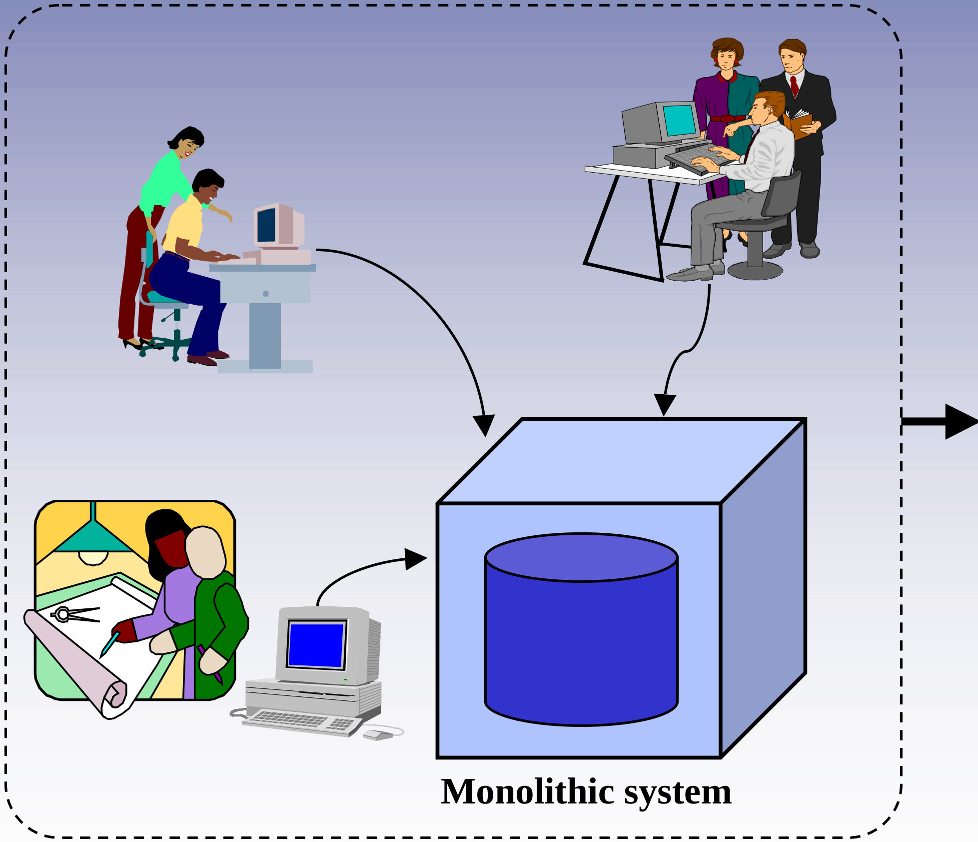
- Industry has an increasing need for tools to capture, represent, exchange and reuse product development knowledge
- Existing generation of CAD/CAM/CAE tools have not been developed to support this new paradigm
- The next generation will… But at what cost?
- NIST Strategic Planning and Economic Assessment Office Study (March 1999):
  - Economic cost due to lack of interoperability in the automotive supply chain: $1 Billion per year (conservative estimate)
  - Similar interoperability costs in aerospace, shipbuilding, construction machinery industries: ~$400M per year
- STEP (ISO 10303) has been successful at reducing interoperability costs, but only because waste due to poor interoperability exists.

Intelligent and Distributed Engineering Design

- Goals
  - Develop representations of knowledge, not currently present in traditional CAD tools.
  - Support exchange of knowledge in the new product development paradigm
  - Avoid proliferation of proprietary formats in commercial software tools
  - Provide a foundation for future standards development
- Fundamental assumption
  - Next- generation CAD/CAM/CAE tools will represent knowledge beyond traditional geometry (function, behavior, specifications, physical decompositions, form-to-function mappings, assembly models…)
- Work is being done *in anticipation* of these needs

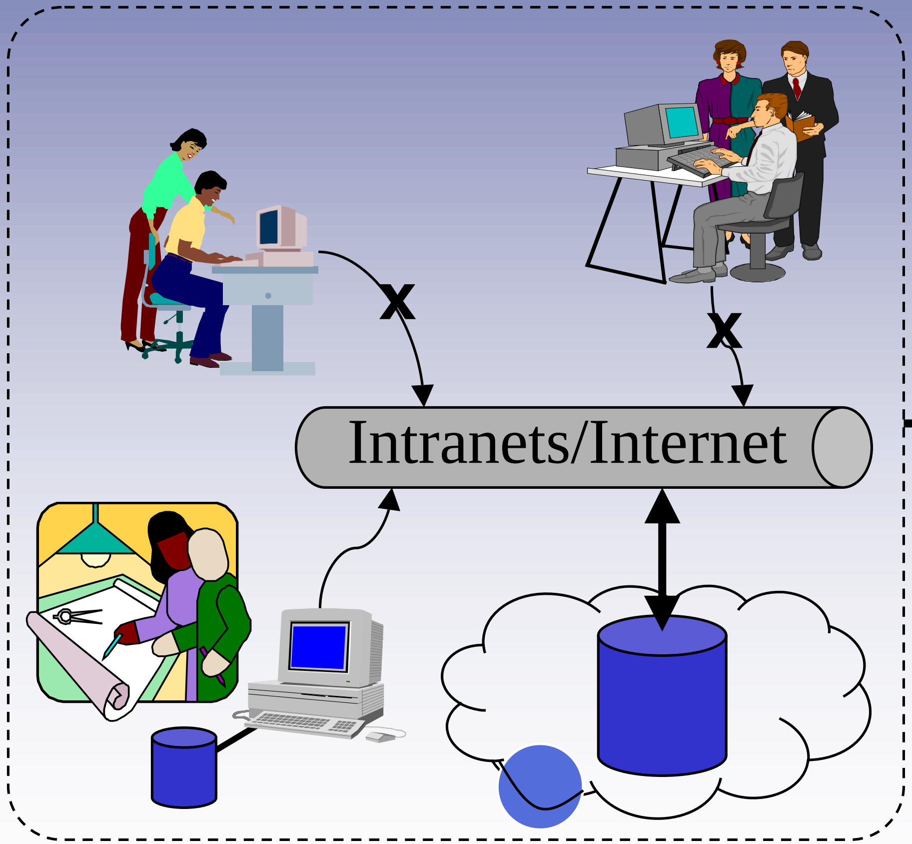
Monolithic Product Development

Monolithic product development platform
(tied to one vendor, expensive, inhibits collaboration, suboptimal)



Our Vision: Intelligent and Distributed Engineering Design

Distributed product development tool suite



Clarifying the Vision

- The key to achieving the vision of next-generation product development is a formal representation that:
  - Is generic
  - Is not tied to any one product development process
  - Captures knowledge used in product development activities
  - Is not tied to a single vendor software solution
  - Is open and non-proprietary

IDED: Areas of Research

- Knowledge-based Interoperability Project
  - Information modeling effort resulting in the development of schema definitions for representation of engineering product development knowledge
- NIST Design Repository Project
  - Development of a distributed software architecture and interfaces for authoring and navigating next-generation engineering design knowledge bases

Knowledge-based Interoperability Project

- Objective
  - To develop an information modeling infrastructure for representing knowledge that spans a broad set of product development activities
- Requirements
  - Formal
  - Generic
  - Independent of product development process
  - Supports IDED
    - Software implementation in a distributed product development environment
    - Capture, exchange, retrieval and reuse of knowledge

Representation: Key to Interoperability

- Product knowledge core
  - Specifications
  - Requirements
  - Physical aspects of the artifact
    - Function or Intended Behavior: what the artifact should do
    - Behavior: how the artifact achieves its function (governed by physical laws)
    - Form: the physical instantiation to achieve a function, including geometry, materials, assembly model, etc.
  - Relationships among these various kinds of knowledge
- Other knowledge requirements include tolerance, production (manufacturing, process planning), and lifecycle information.

Knowledge-based Interoperability Project

- Current status:
  - Schemata defined for
    - Artifact
    - Function
    - Associated flows
    - Form (high level)
  - Early development
    - Detailed form
    - Tolerance information
    - Manufacturability
  - Placeholders (informal capture)
    - Specifications
    - Behavior
    - Constraints
    - Relationships
  - Additional enhancements
    - Assembly model
    - Design rationale
    - Manufacturing (process)
    - Other lifecycle knowledge
- Addressing terminological issues – enabling the formal representation of taxonomies and ontologies.

Enabling Knowledge Exchange Using XML

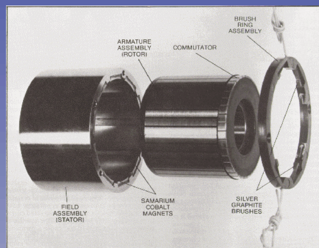
- Extensible Markup Language (XML):
  - Similar to HTML but allows user-defined tags, referencing mechanisms, etc.
  - Increasing adoption of XML in the IT world
  - Emerging support in common tools such as web browsers and word processors, making raw data more readily interpretable
  - For use as a neutral format for exchange of knowledge between vendor-specific database formats

The NIST Design Repository Project

- Goal
  – Development of a distributed software architecture and interfaces for authoring and navigating next-generation product development knowledge bases
- Key technical aspects
  – Use of product development knowledge representation core
  – Java-based distributed architecture
  – Web-based design repository interfaces
  – Development of prototype artifact repositories
- Current focus is on design repositories, but modular structure readily extends to other kinds of knowledge

Design Repository: Information Types

Images, drawings, tables



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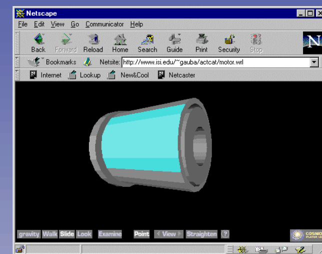

Artifact models

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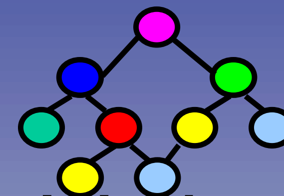

knowledge base, domain theory

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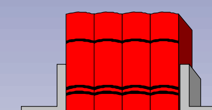

Documentation

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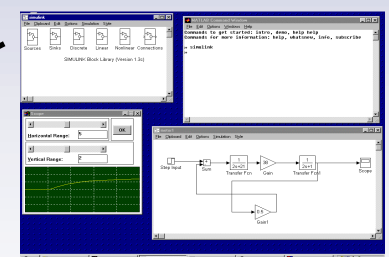

Simulation models

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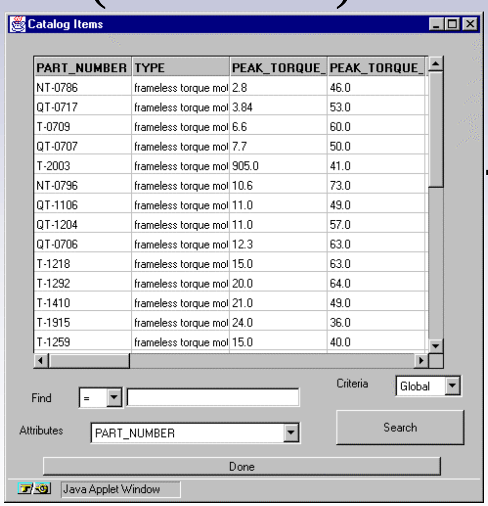
Regular catalogs (electronic)



Catalog Items

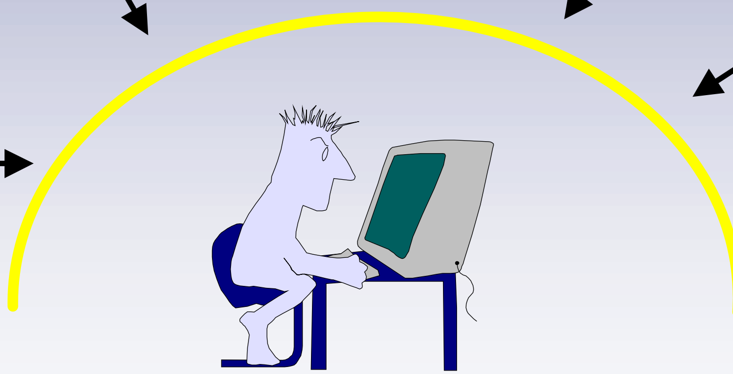
PART_NUMBER	TYPE	PEAK_TORQUE_	PEAK_TORQUE_
NT-0786	frameless torque mot	2.8	46.0
QT-0717	frameless torque mot	3.84	53.0
T-0709	frameless torque mot	6.6	60.0
QT-0707	frameless torque mot	7.7	50.0
T-2003	frameless torque mot	905.0	41.0
NT-0796	frameless torque mot	10.6	73.0
QT-1106	frameless torque mot	11.0	49.0
QT-1204	frameless torque mot	11.0	57.0
QT-0706	frameless torque mot	12.3	63.0
T-1218	frameless torque mot	15.0	63.0
T-1292	frameless torque mot	20.0	64.0
T-1410	frameless torque mot	21.0	49.0
T-1915	frameless torque mot	24.0	36.0
T-1259	frameless torque mot	15.0	40.0

Find = Criteria Global

Attributes PART_NUMBER Search

Done

Java Applet Window



Designer

Courtesy Peter Will, USC-ISI

The NIST Design Repository Project

- Focus on web-based interfaces
  - Enables distributed access to distributed data
  - Platform-independent
  - Requires no special software aside from a web browser
- Knowledge repository browser
  - Allows user to browse a knowledge repository
  - Multiple modes of navigation
- Knowledge repository editor
  - Allows creation and editing of knowledge repositories
  - Intelligent interface reduces development effort

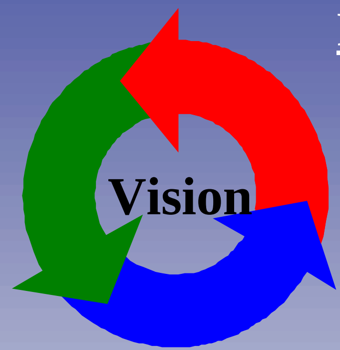
The NIST Design Repository Project

- First prototype: tool suite consisting of
  - ObjectStore™ (commercial OODBMS)
  - Design compiler
  - Design extractor or “decompiler”
  - Stand-alone information browser application
  - Web-based information browser
  - Web-based repository editor and design modeler
  - Web-based visualization using VRML

The NIST Design Repository Project

- Ongoing work
  - Migration to a new Java-based architecture
  - Using generic technologies to interface to multiple commercial databases (JDBC for DB access, XML for knowledge exchange)
  - Extending functionality of system
  - Expanding tool suite (translators/compilers)
  - Leveraging NIST efforts with research by academic partners

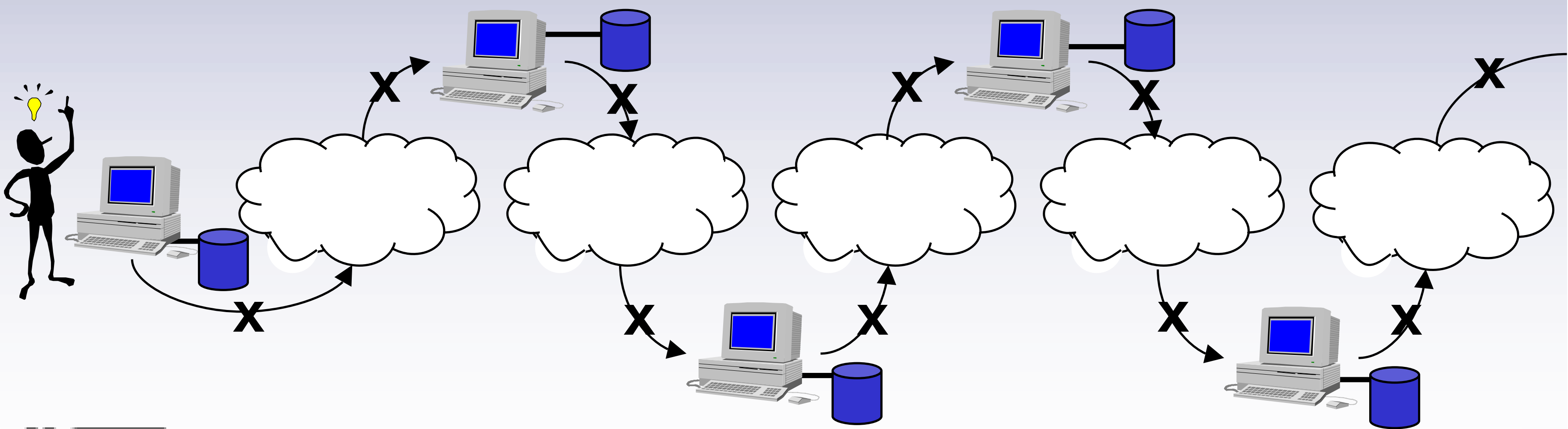
Relating the Efforts to the Vision



Analysis
Evaluation of knowledge representation needs

Prototype implementation
NIST Design Repository Project

Infrastructure development
Knowledge-based Interoperability Project



Impact

- The two efforts described have significant potential impact on:
  - Interoperability costs in next-generation product development systems
  - Supply chain integration (addressing not business process integration, but knowledge exchange in the virtual enterprise)
  - Time to market, through improved use and *reuse* of product development knowledge
  - Enabling a computer-aided product development paradigm that improves the ability of small-to-medium sized business to compete

The NIST Design Repository Project

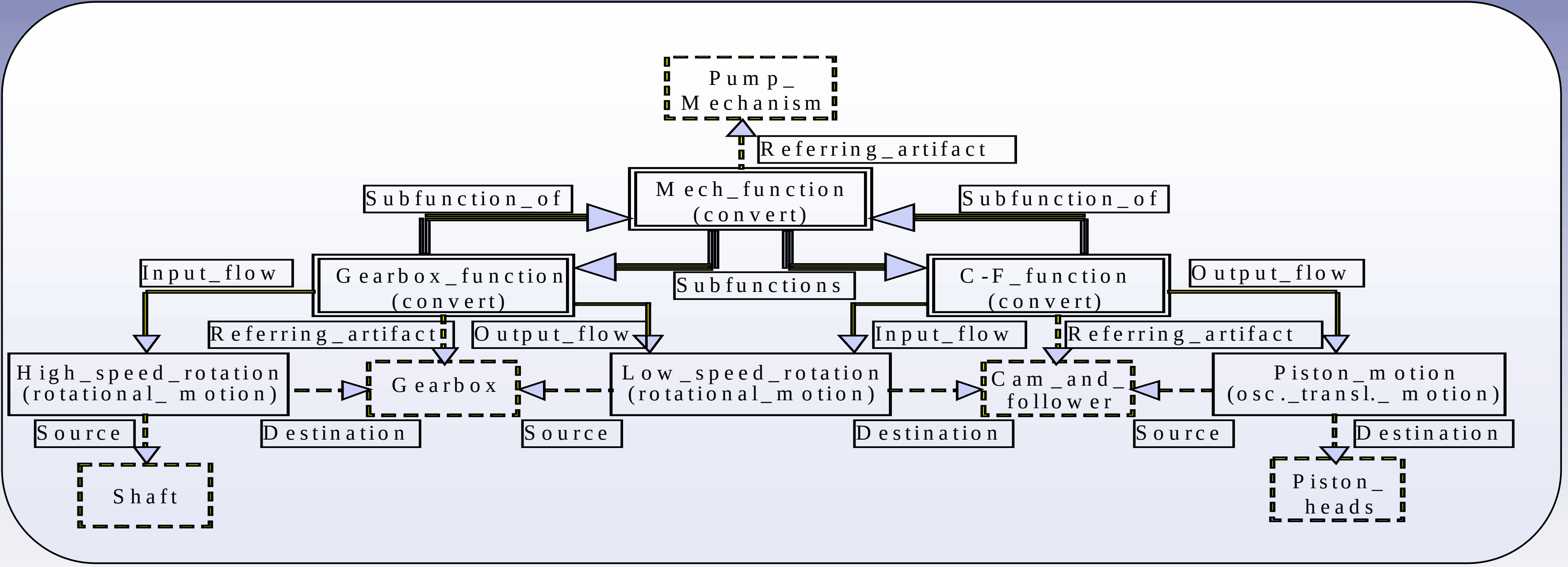
Demonstration

Schema Example: Representation of Function

Function Schema

Function		
Name	string	
Type	[Generic_function_class]	
Information	[Information]	
Input_flow	{[Flow]} (or NULL)	
Output_flow	{[Flow]} (or NULL)	
Subfunctions	{[Function]}	(or NULL)
Subfunction_of	[Function]	(or NULL)
Referring_artifact	[Artifact]	

Representation Example:
Schematic of Pump Mechanism Data Entities



Interface Example:
Design Repository Browser